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MCDONNELL DOUGLAS TECHNICAL SERVICES CO.
HOUSTON ASTRONAUTICS DIVISION

SPACE SHUTTLE ENGINEERING AND OPERATIONS SUPPORT

DESIGN NOTE NO. 1.3-DN-C0203-007

AN EVALUATION OF THE MSBLS/NOSE BOOM INTERFERENCE FOR THE APPROACH AND LANDING TEST

AVIONICS SYSTEM ENGINEERING

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(NASA-CR-151015) AN EVALUATION OF THE MSBLS/NOSE BOOM INTERFERENCE FOR THE APPROACH AND LANDING TEST (McDonnell-Douglas Technical Services) 27 p HC $4.00 CSCL 17G

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1.0 SUMMARY

The backup air data subsystem of Orbiter 101 utilizes probes mounted on a boom which extends approximately 17 feet forward of the Orbiter nose. Concern that this obstruction could cause Microwave Scan Beam Landing System (MSBLS) data dropout during the Autoland flight phase of the Approach and Landing Test (ALT) led to the analysis described herein. The results of the analysis indicate that there will be no interference from the nose boom to cause MSBLS data dropout for the flight conditions under which the ALT is to be performed. Additional analysis considering approach trajectories in more extreme wind conditions than anticipated for the ALT also indicates that the nose boom creates no interference.

2.0 INTRODUCTION

The baselined radio frequency airborne Navigation Aid (NAVAID) for the Shuttle approach and landing is the MSBLS. The function of the MSBLS is to provide navigation information in the form of range, elevation, and azimuth data relative to two ground transmitters adjacent to the runway at the landing site (Figure 1).

For ALT a Backup Air Data System, which utilizes a 17 foot nose boom, will be used to calibrate the primary air data systems and supply information to the Backup Flight Control System (BFCS) and Displays. It is the nose boom and it's proximity to the MSBLS onboard antennas that has caused concern relative to MSBLS data dropout during the Autoland flight phase of the ALT.

It is the purpose of this design note to exhibit the results of an analysis performed to evaluate the possibility of MSBLS/nose boom

interference. Figures 2a and b show representations of the airborne RDP relative to ground station geometry and the airborne to ground station MSBLS look angle geometry respectively. These figures will lend clarity to the nose boom interference problem.

3.0 DISCUSSION

The primary purpose of this analysis is to determine if the nose boom interferes with the MSBLS signal reception during the Autoland flight phase of the ALT. Interference can result from two sources. (1) A physical obstruction to signal reception such as could be the case with the nose boom, and (2) Rate of change of power received. The Automatic Gain Control (AGC) has the ability to track changes in power received of +3 to -2 decibels/second (db/sec). Therefore changes which exceed these rates would cause the MSBLS to drop signal lock and result in data dropout.

Figure 3, a Radiation Distribution Pattern (RDP), is a Ku Band antenna pattern obtained from Rockwell and is representative of the antenna to be used on the Orbiter. The numbers on the RDP represent the normalized antenna gain as a function of pitch and yaw antenna look angles. The interference created by the nose boom is clearly defined in the lower portion of the RDP. Rapid motion in either pitch or yaw antenna look angles while in this region, (approximately +12° in pitch) would constitute MSBLS/nose boom interference and could cause data dropout by exceeding the AGC tracking rate (Reference 1).

The technique used in this analysis is as follows: Obtain the time histories of both pitch and yaw antenna look angles from the ALT approach trajectory utilizing various wind conditions and the Space

Shuttle Functional Simulator (SSFS). This was done to ascertain if the antenna look angles fall in the lower portion of the RDP and create interference due to the inability of the AGC to track the signal in that portion of the RDP.

In addition, the following procedure was used to check the gain margin to ensure that it is within limits. Read a corresponding normalized gain value of the airborne antenna (G_r) from the RDP Figure 3, as a function of pitch and yaw look angles. Subtract the RDP gain value from 5, (the assumed maximum gain). Calculate slant range to the ground antenna, (applying the root sum squared technique) using the altitude of the airborne antenna and the ground range to the ground antenna. Inserting the value calculated above, along with the known values into the power received equation,

$$P_r = P_t + G_t + G_r + 10 \log_{10} \left[\frac{\lambda}{4\pi R}\right]^2$$

the total power received can be calculated.

Where:

P_r = power received (dbM)

P_t = transmitted power (+60 db)

G_t = ground antenna gain
+31 db for the elevation antenna
+27 db for the azimuth antenna

G_r = gain of the airborne antenna
(assumed 5 db maximum)

λ = wave length (assumed .02 meters)

R = slant range

The power received calculation was made assuming a clear day, (no rain losses) and no airborne waveguide and miscellaneous losses were used. The receiver threshold for power received for elevation and azimuth signals

is -74dbM and -77 dbM for the Distance Measuring Equipment (DME). The DME signal emanates from the same location as the azimuth signal. Therefore, any signal which falls below -74 or -77 dbM respectively would constitute loss of signal.

4.0 RESULTS

The simulations evaluated were, (1) nominal trajectory with no winds, (2) nominal trajectory with headwinds and gusts, (3) nominal trajectory with crosswinds (left to right, which causes the vehicle to yaw away from the ground station) and gusts.

Figures 4,6,8, and 10 show the time history of pitch (THETA) and yaw (PSI) antenna look angles in degrees as a function of time in seconds for the elevation station. These figures represent trajectories 1,2,3, and 4 respectively. In none of the cases evaluated, do the pitch antenna look angles exceed +10° prior to threshold. Only after threshold passage do both pitch and yaw angles began to diverge which is as expected in as much as the vehicle is approaching ground station fly-by and loss of signal from the elevation station would occur. No nose boom interference is seen in the trajectories analyzed for the elevation station.

The ability of the MSBLS air borne unit to respond to changes in power received is of concern. The airborne AGC can track changes in power received in the range of +3 to -2 db/sec. As a result of this analysis, the rate of change seen in all trajectories analyzed, (+2.45 to -1.72 db/sec) did not exceed these rates for the elevation station. Therefore AGC tracking is not a problem.

Figures 5,7,9 and 11 show a time history of power received in decibel meters (dbM) as a function of time in seconds and slant range in feet for the elevation station. The figures represent trajectories 1,2,3 and 4 respectively. As expected, the power received improves as the distance between the airborne and ground antennas decreases. Furthermore, the power received does not go below -74 dbM and there is no loss of signal due to lack of power received. Therefore there is no evidence of nose boom interference.

Figures 12,14,16 and 18 show the time history of pitch (THETA) and yaw (PSI) antenna look angles in degrees as a function of time in seconds for the azimuth/DME station. These figures represent trajectories 1,2,3, and 4 respectively. In none of the cases evaluated do the pitch antenna look angles exceed +8°. Therefore inasmuch as the pitch antenna look angles did not move through the lower portion of the RDP (Figure 3) the condition for nose boom interference is not present.

Figures 13,15,17, and 19 show the time history of power received in dbM as a function of time in seconds and slant range in feet for the azimuth/DME station. These figures represent trajectories 1,2,3, and 4 respectively. As was the case with the elevation antenna, the power received improves as the slant range decreases between the airborne and ground, and the power received does not go below -74 dbM for the azimuth or -77 dbM for the DME antennas.

There is a discontinuity which occurs in figures 15,17, and 19. The discontinuity represents a limitation in the printer used to print

Figure 3. The vehicle attitude during these discontinuities was one of nose below the tail and would therefore improve signal reception. Additionally the changes in power received, (+0.97 to - 0.79 db/sec) do not exceed the AGC tracking rates. There was therefore, no data dropout due to nose boom interference for the azimuth/DME ground antennas.

5.0 CONCLUSION

The results of this analysis indicate that for the particular trajectories and conditions analyzed, that the onboard MSBLS will be able to acquire and retain lock. Except for the discontinuities noted in the results, the system performed as expected. The vehicle pitch attitude did not reach a position which would cause the nose boom to interfere with MSBLS signal reception. Furthermore, the vehicle yaw did not attain yaw rates which would cause the AGC to drop signal lock from either elevation or azimuth/DME stations.

It can be concluded based on the conditions of this analysis that there is no MSBLS/nose boom interference.

It should be noted however, that should the conditions on which this analysis was based be changed, it is recommended that an analysis based on the new conditions be made.

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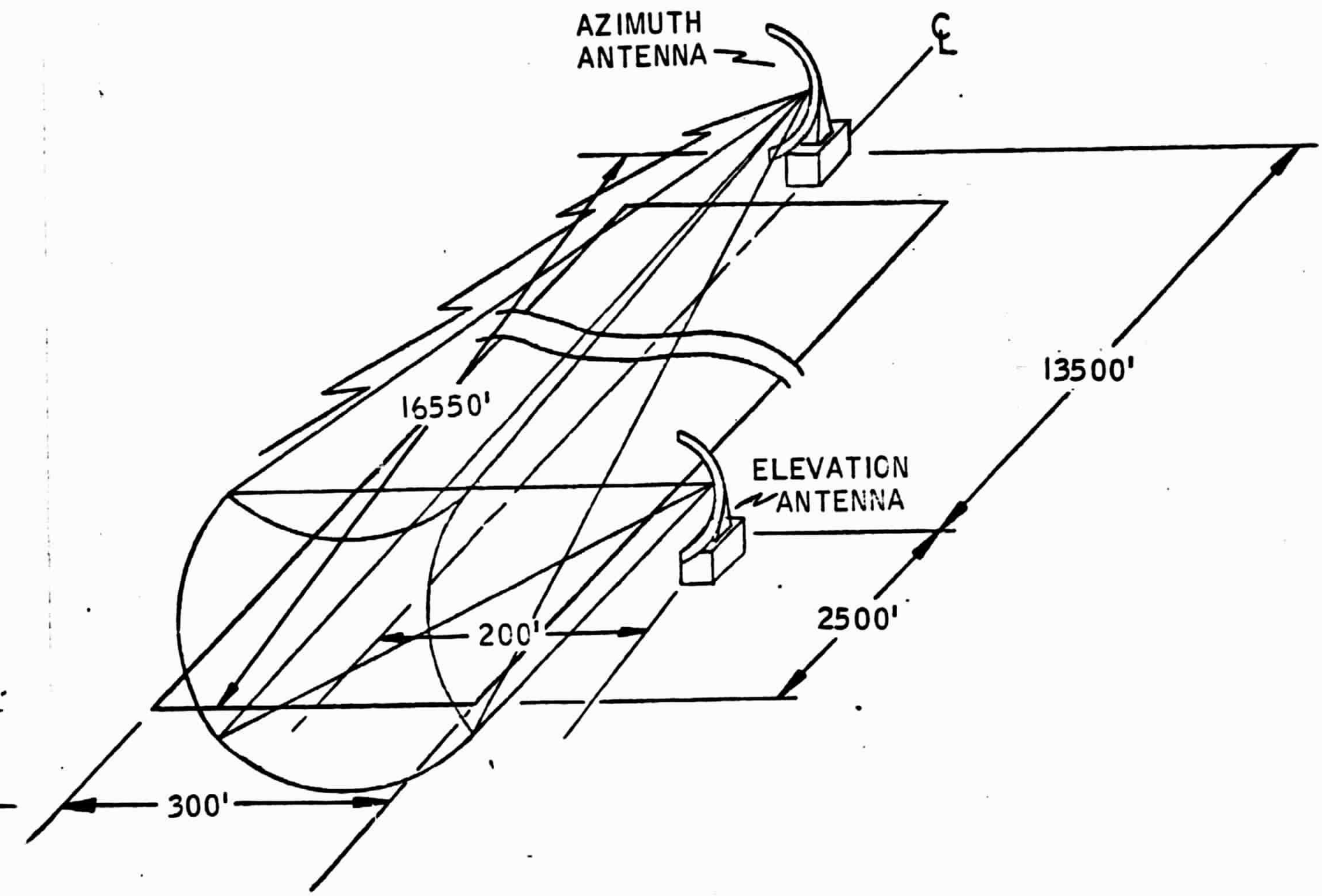

MSBLS GROUND STATION GEOMETRY

FIGURE I

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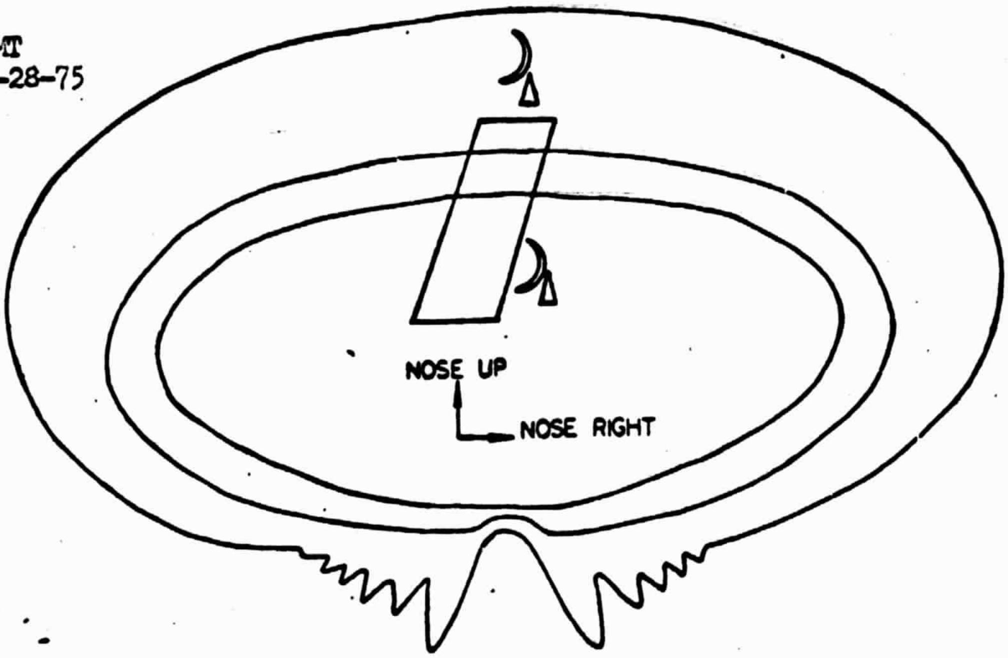
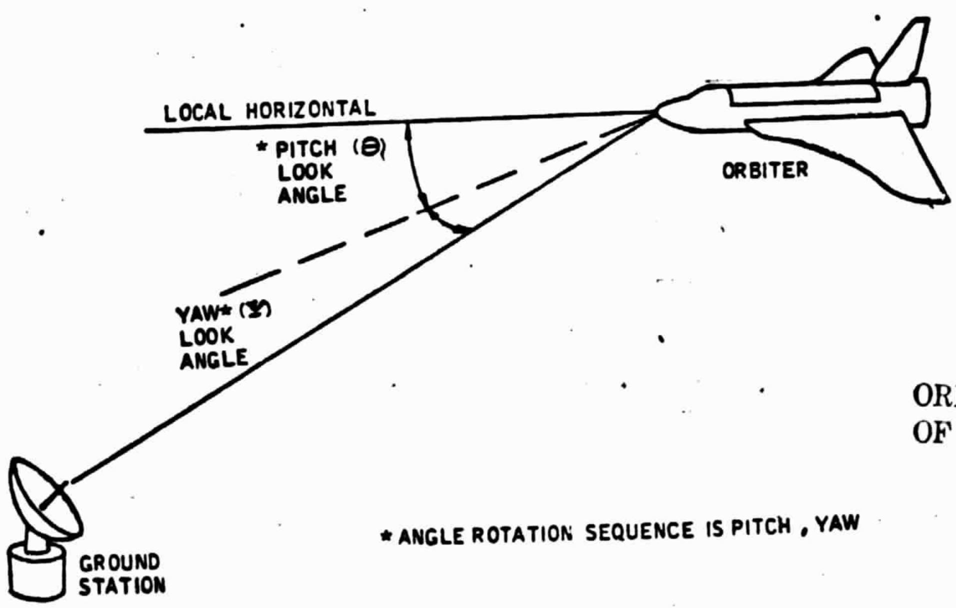


RDP / GROUND STATION GEOMETRY

FIGURE 2A



* ANGLE ROTATION SEQUENCE IS PITCH, YAW

AIRBORNE TO GROUND STATION MSBLS LOOK ANGLE

FIGURE 2B

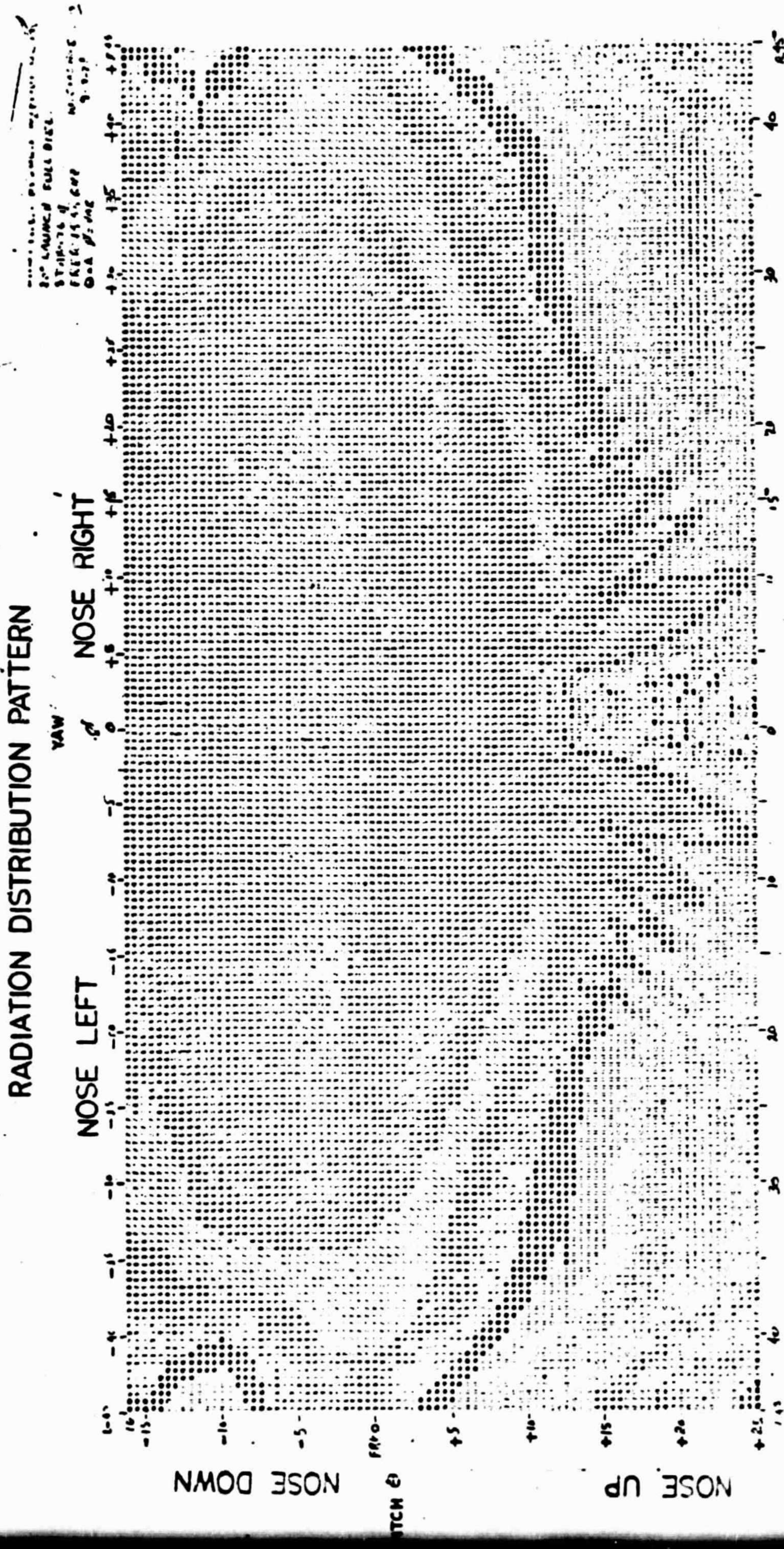


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FIGURE 3

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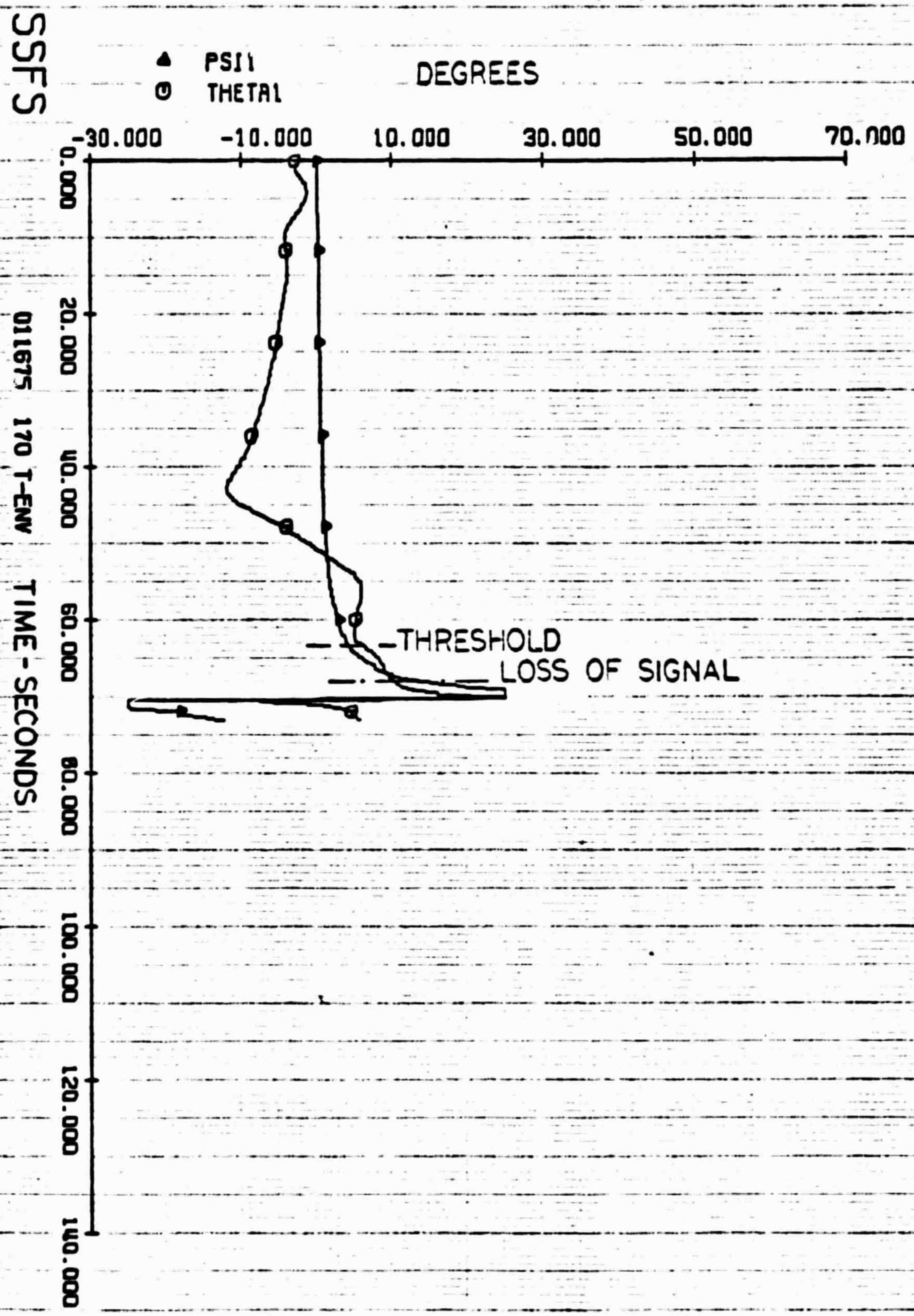
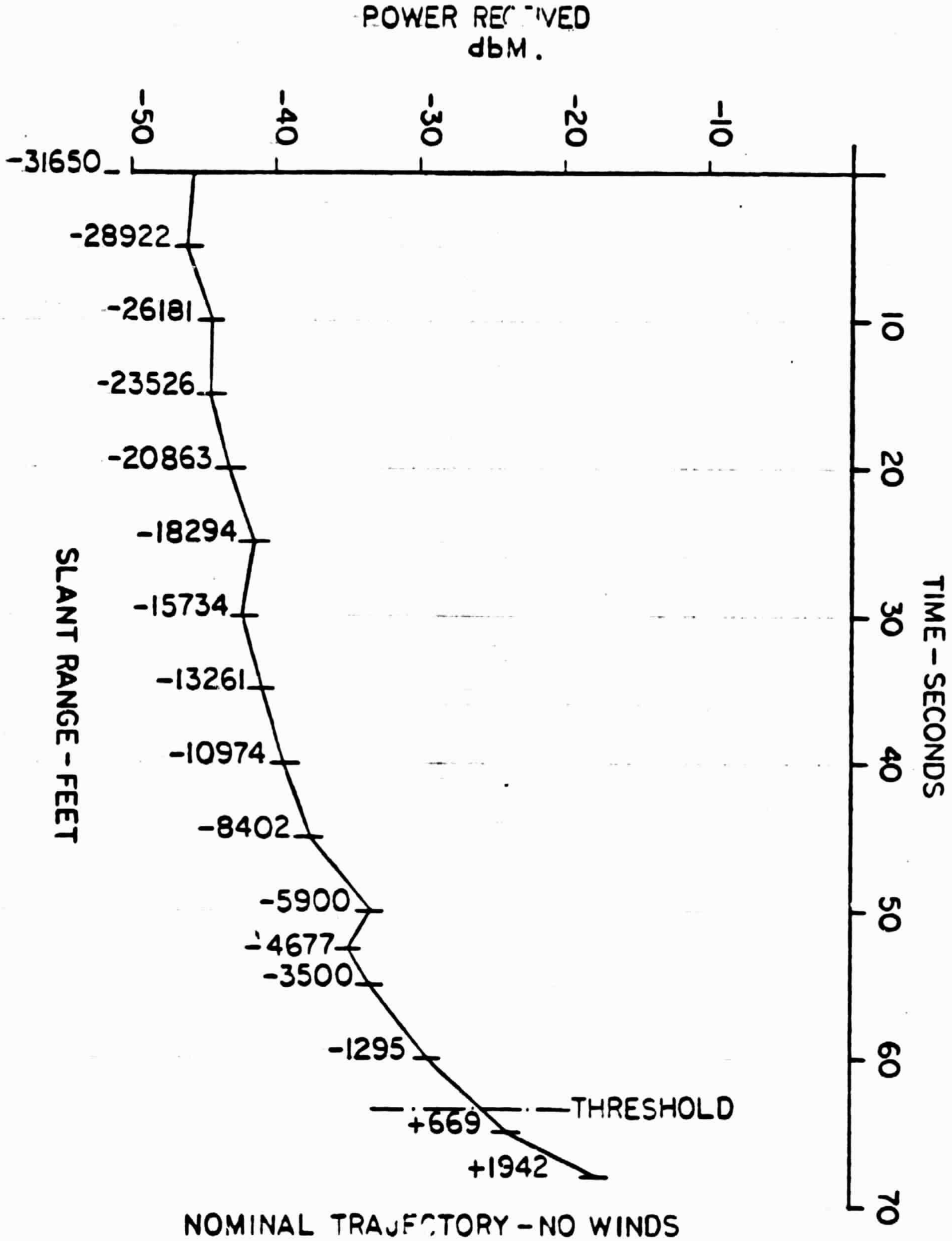


NOMINAL TRAJECTORY—NO WINDS
ELEVATION STATION

FIGURE 4



NOMINAL TRAJECTORY - NO WINDS
ELEVATION STATION

FIGURE 5

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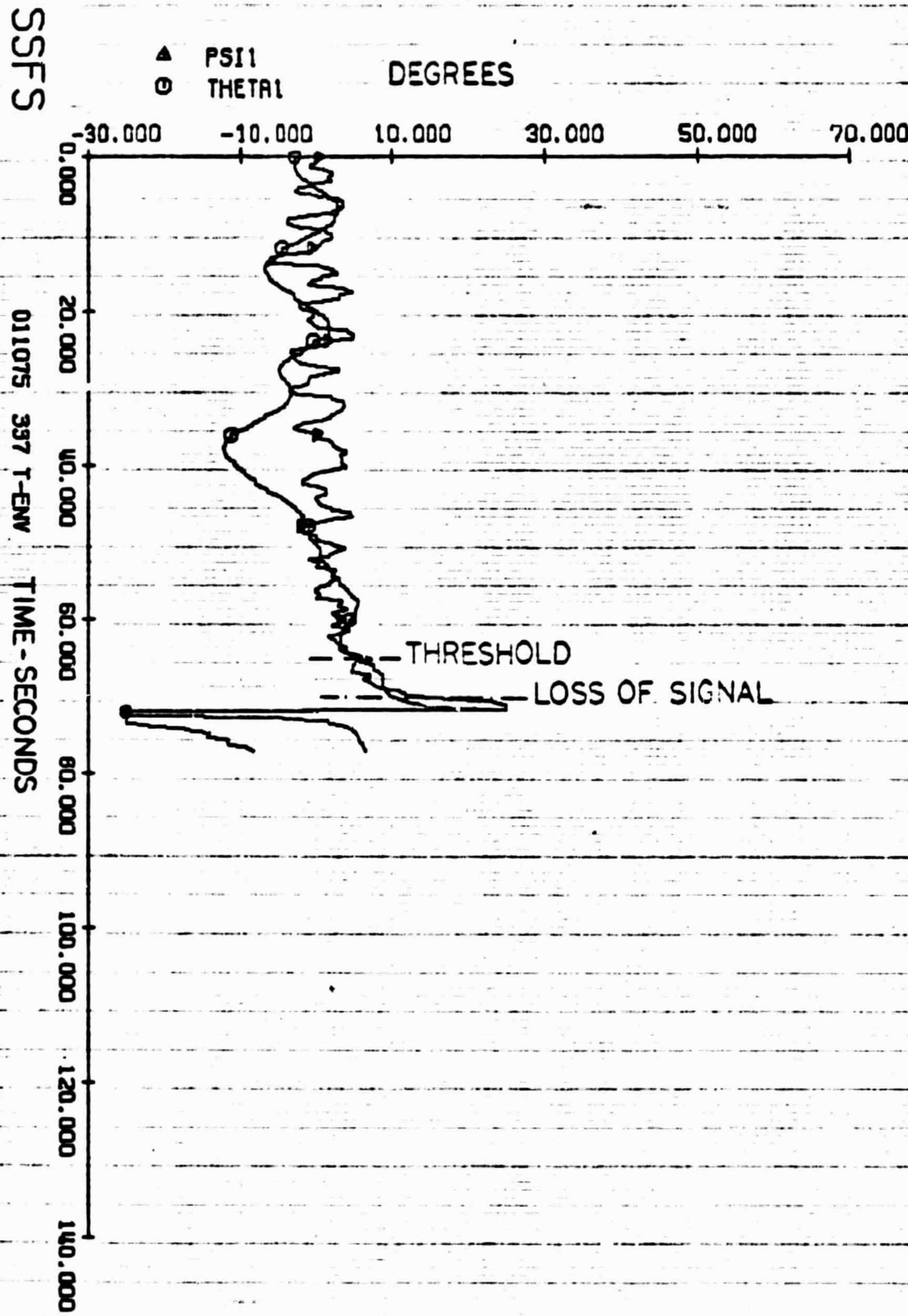
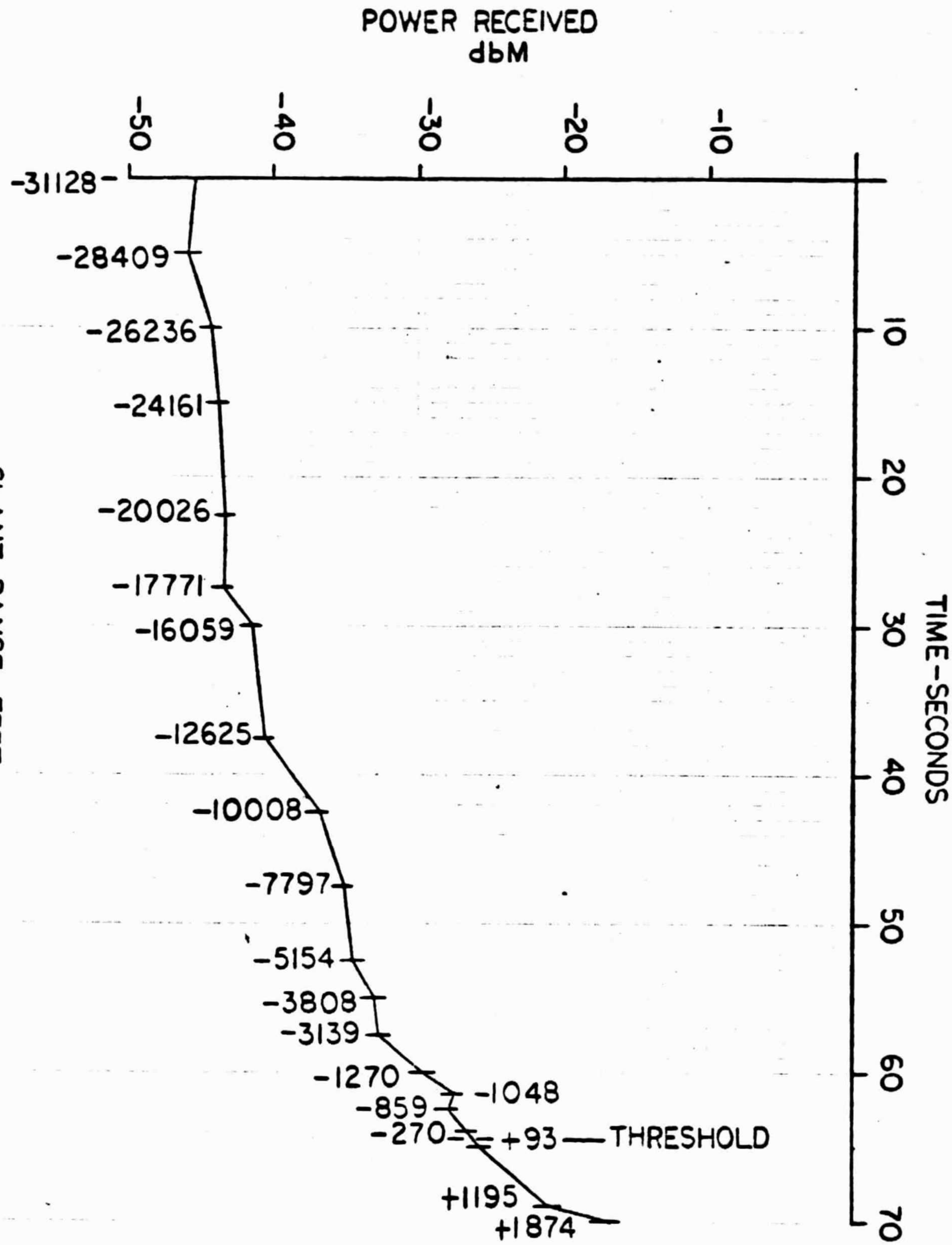


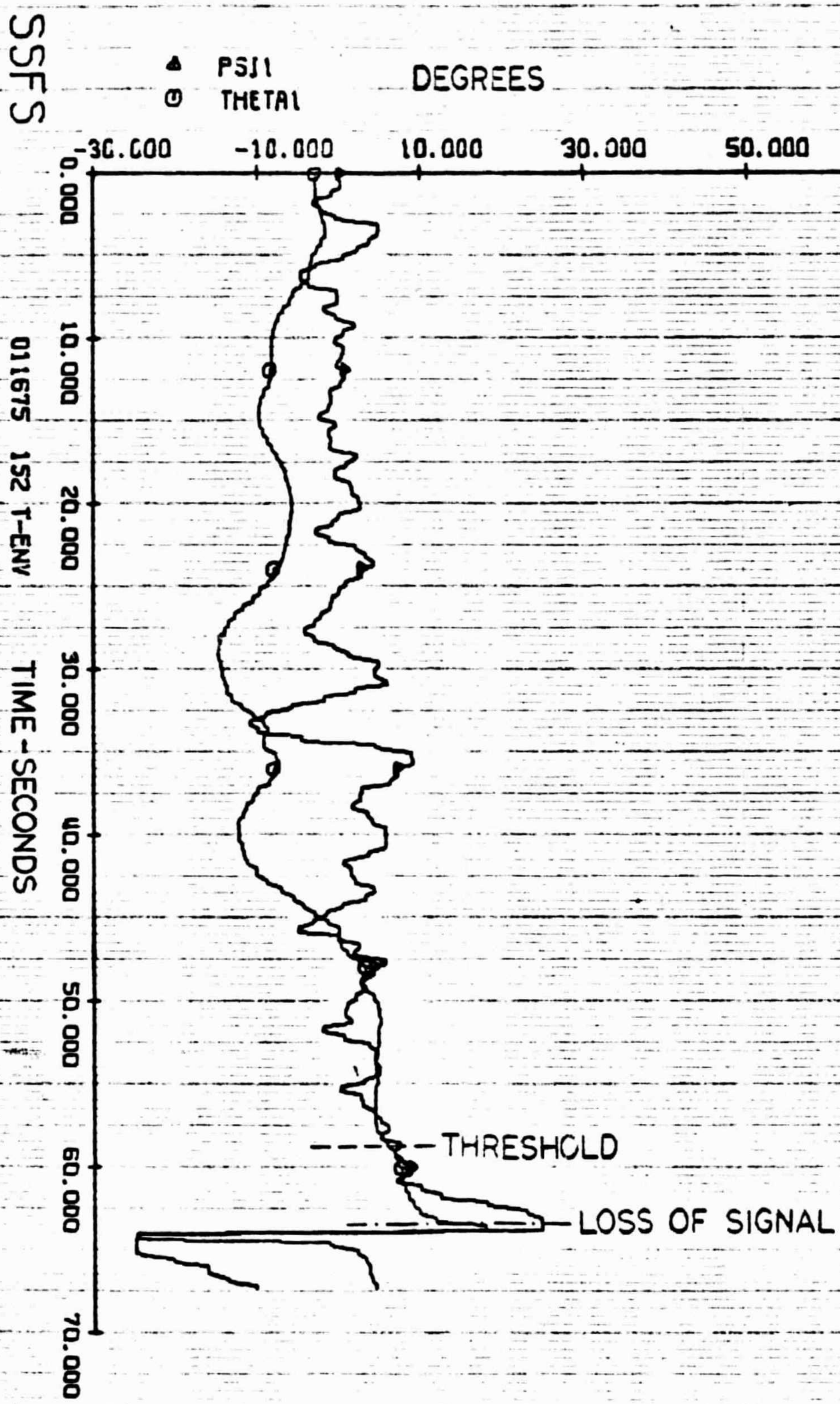
HEADWINDS WITH GUSTS
ELEVATION STATION

FIGURE 6



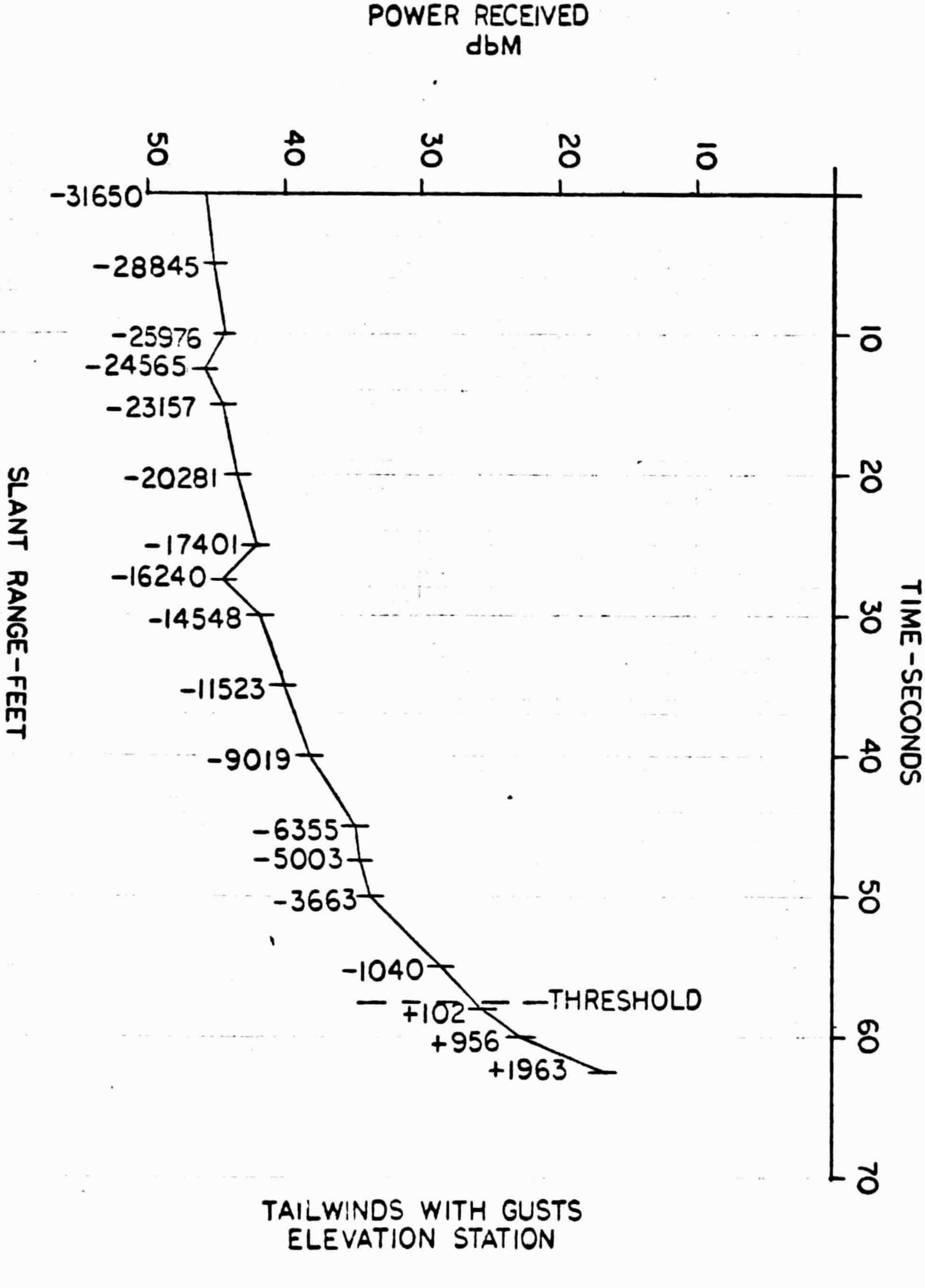
HEADWINDS WITH GUSTS
ELEVATION STATION

FIGURE 7



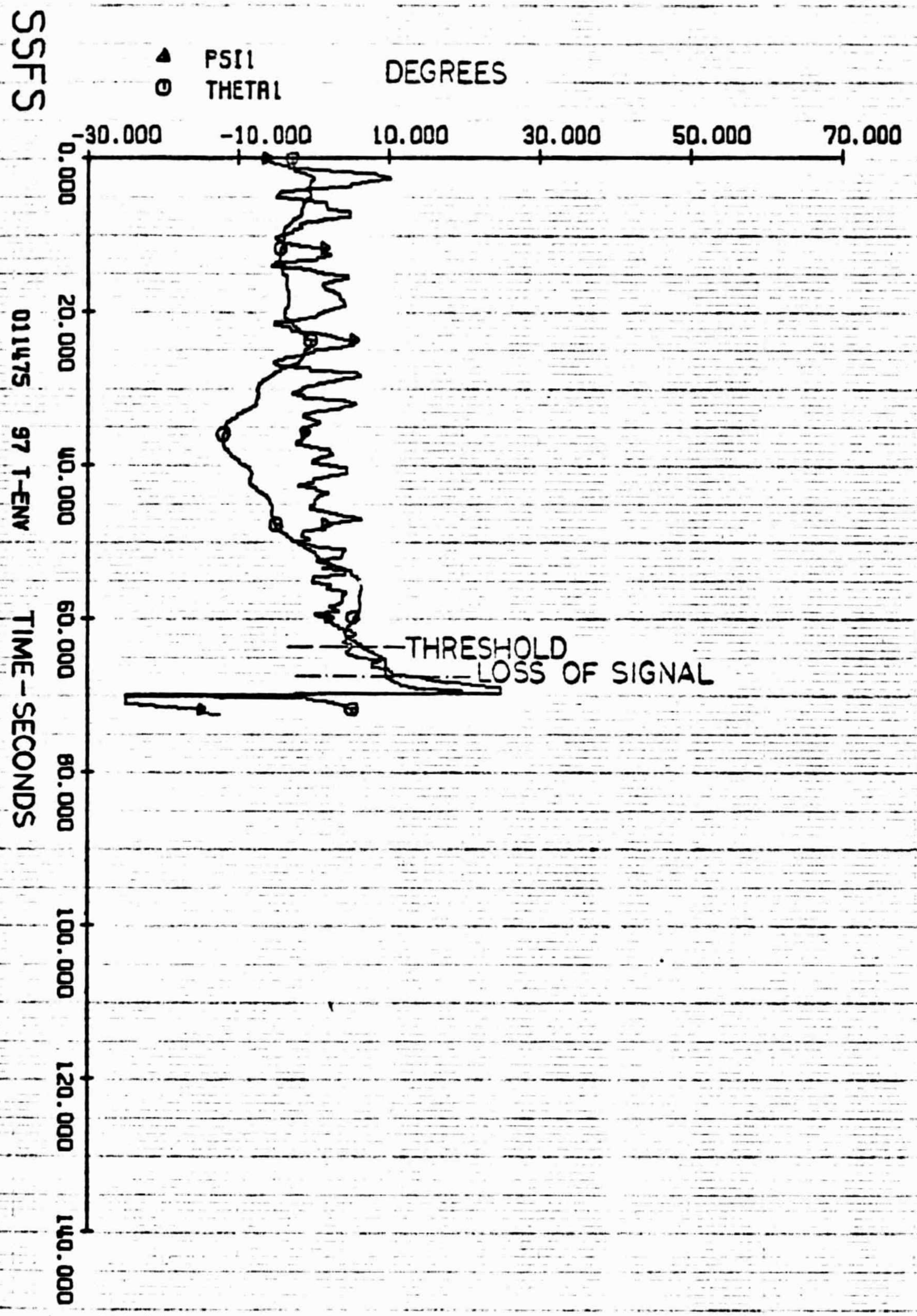
TAILWINDS WITH GUSTS
ELEVATION STATION

FIGURE 8



TAILWINDS WITH GUSTS
ELEVATION STATION

FIGURE 9



CROSSWINDS-LEFT TO RIGHT
ELEVATION STATION

FIGURE 10

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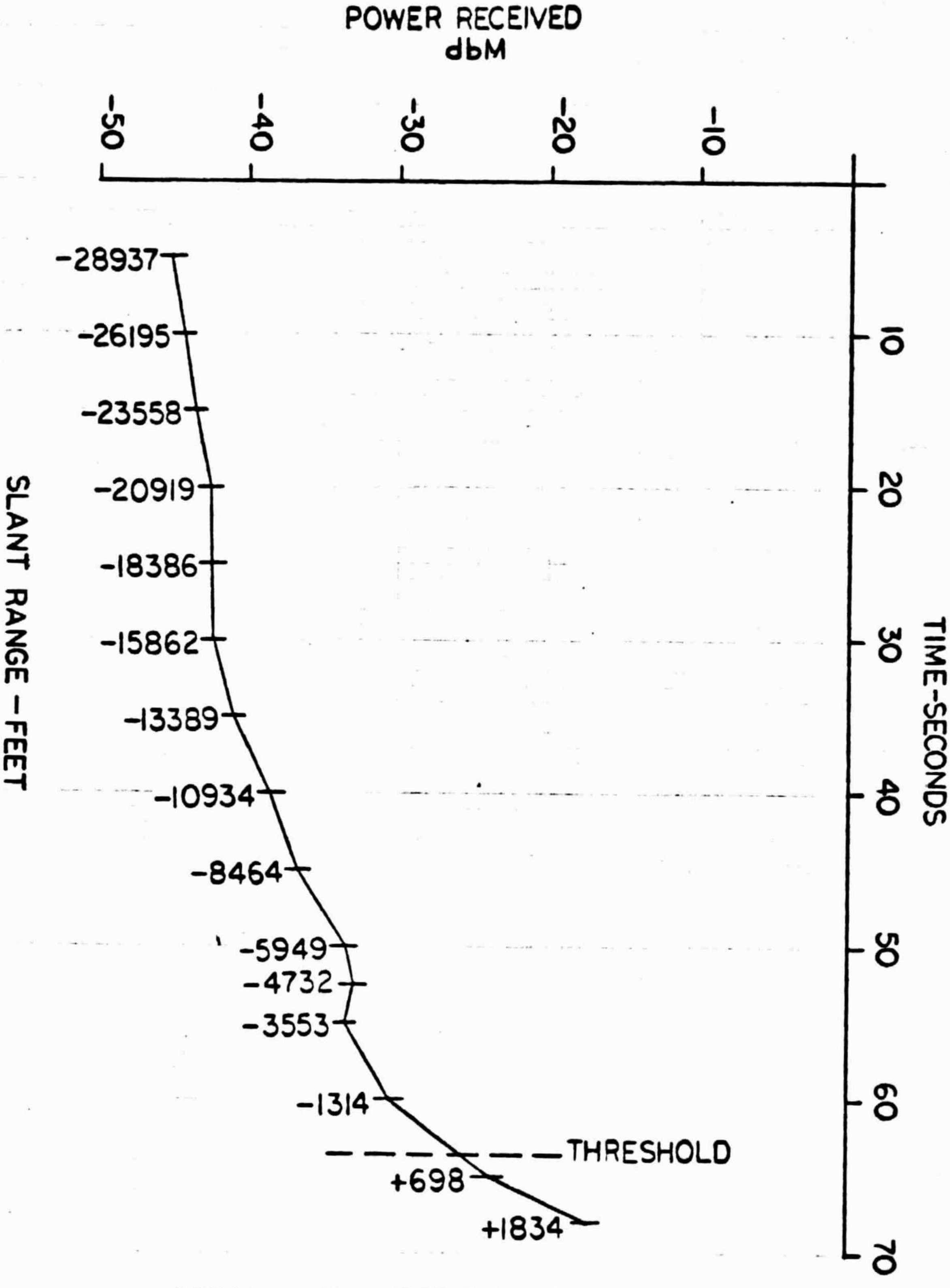

CROSSWINDS-LEFT TO RIGHT
ELEVATION STATION

FIGURE 11

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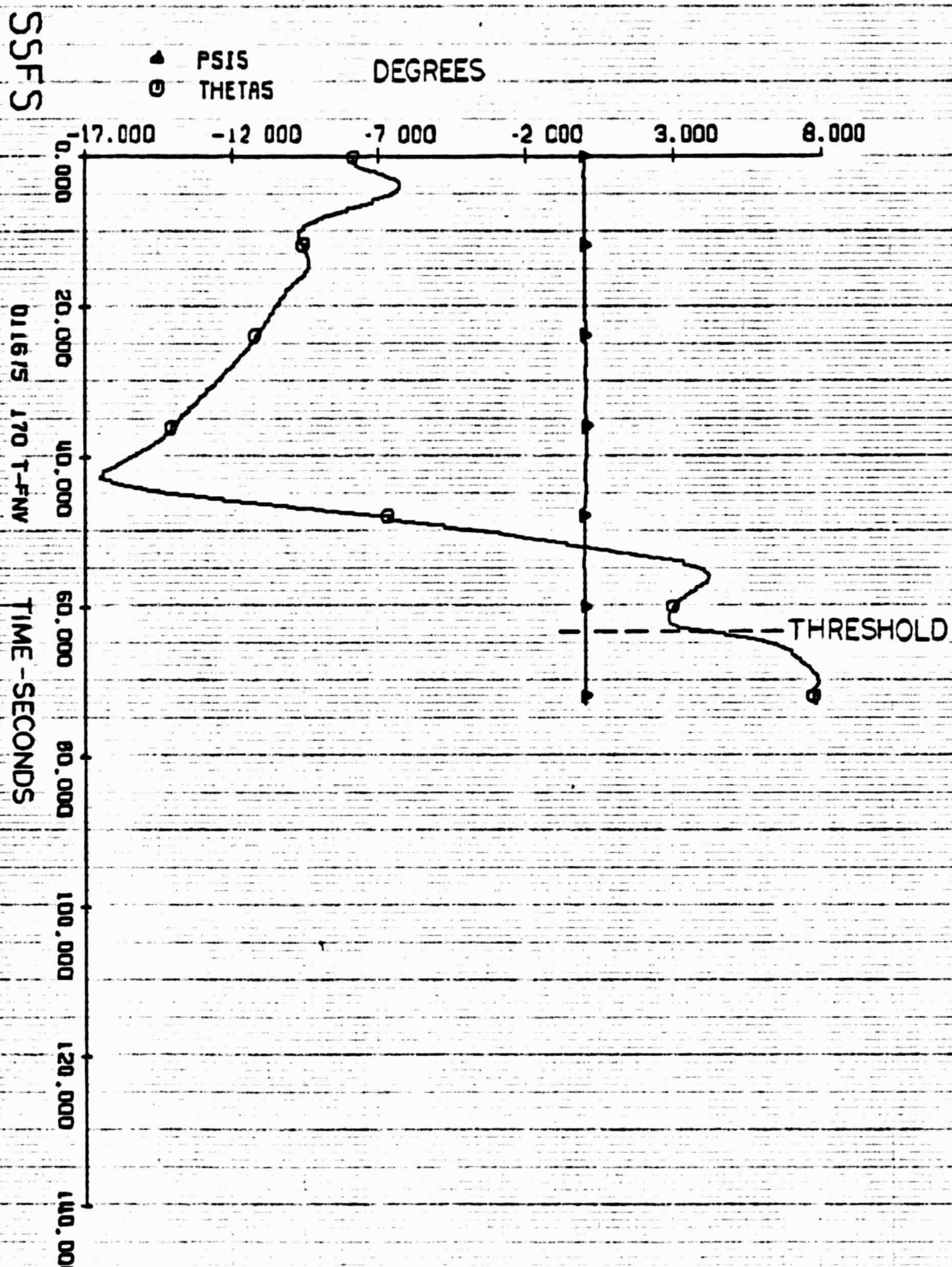

NOMINAL TRAJECTORY-NO WINDS
AZIMUTH STATION

FIGURE 12

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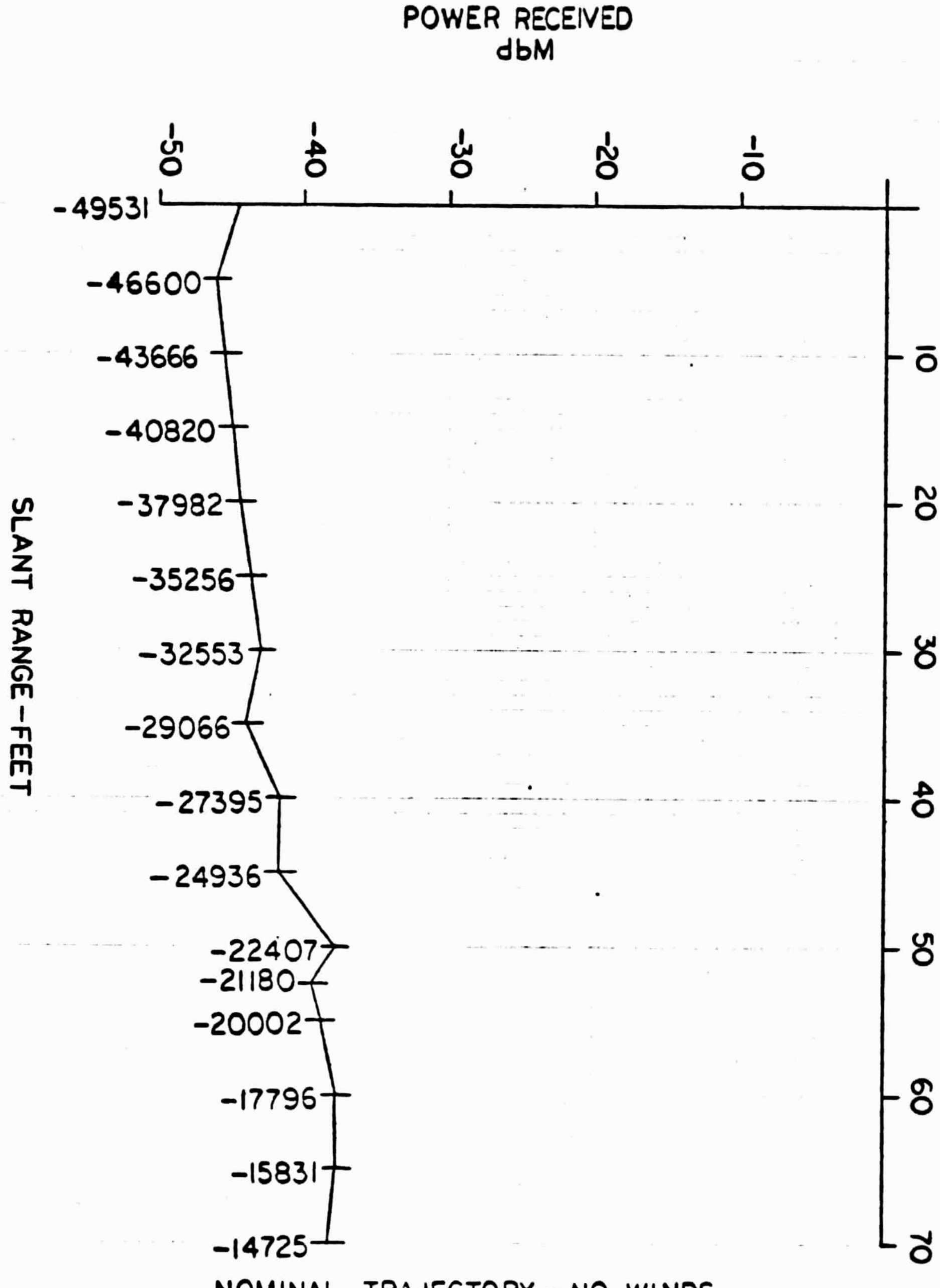
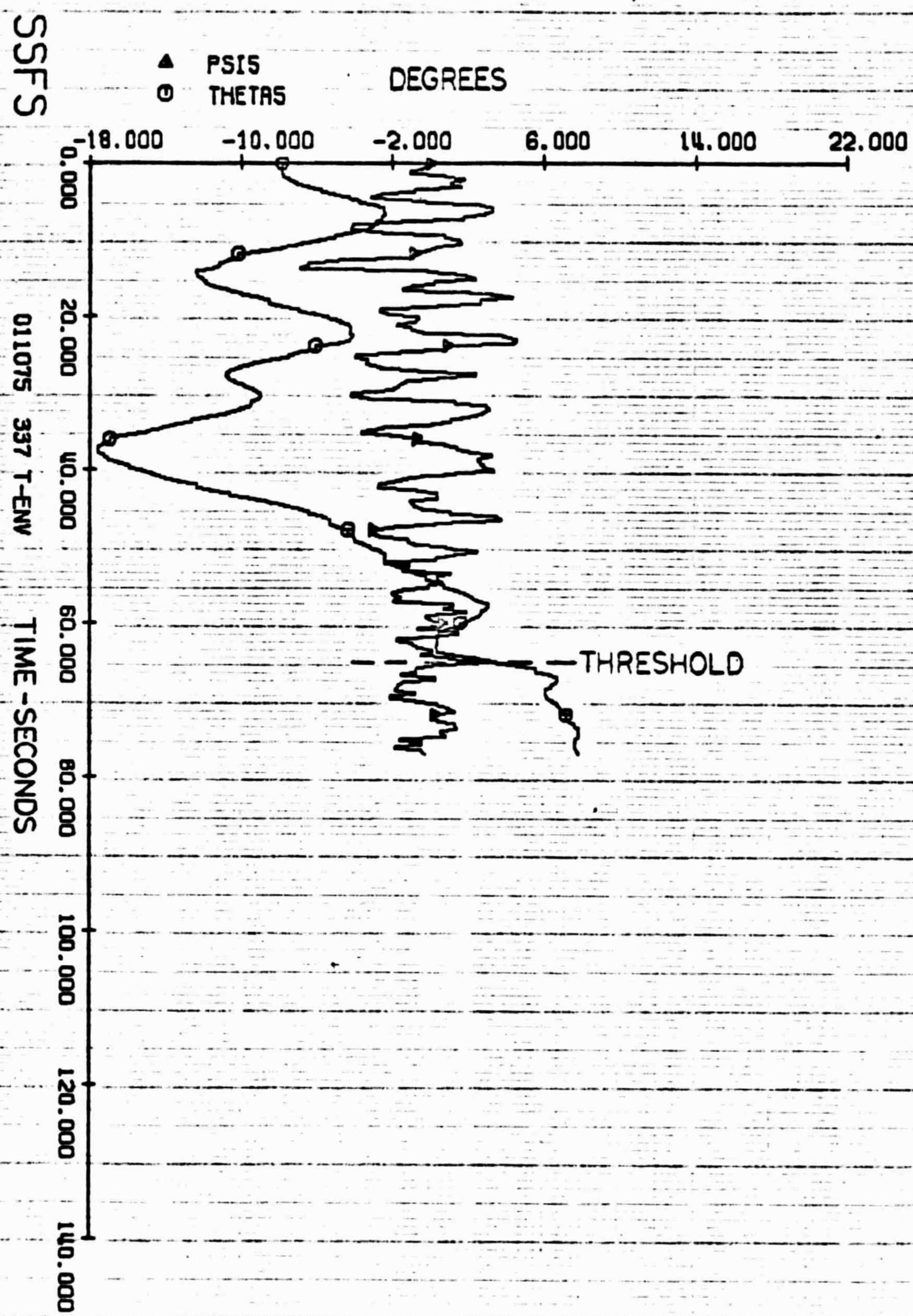


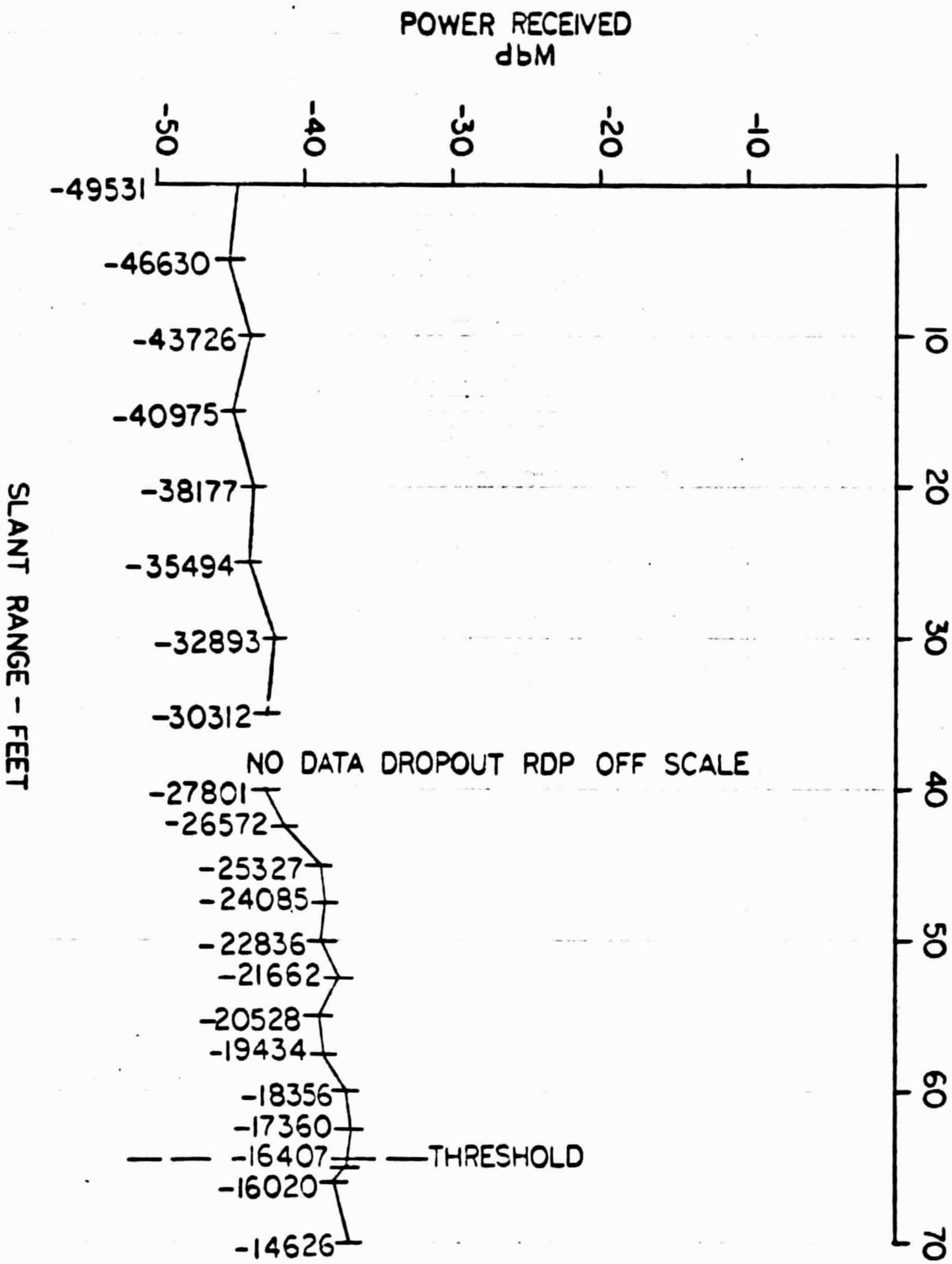
NOMINAL TRAJECTORY - NO WINDS
AZIMUTH STATION

FIGURE 13



HEADWINDS WITH GUSTS
AZIMUTH STATION

FIGURE 14



HEADWINDS WITH GUSTS
AZIMUTH STATION

FIGURE 15

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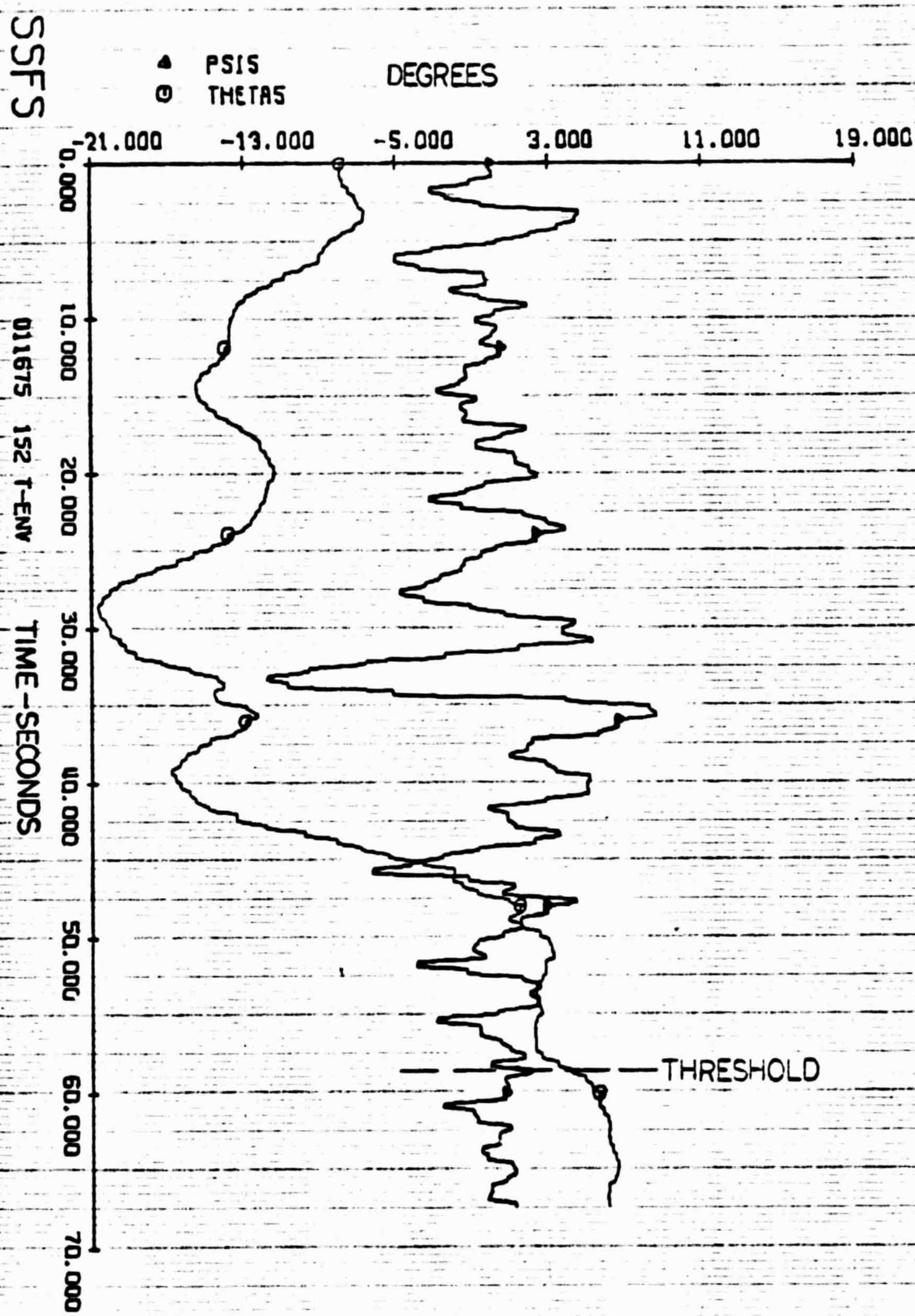

TAILWINDS WITH GUSTS
AZIMUTH STATION

FIGURE 16

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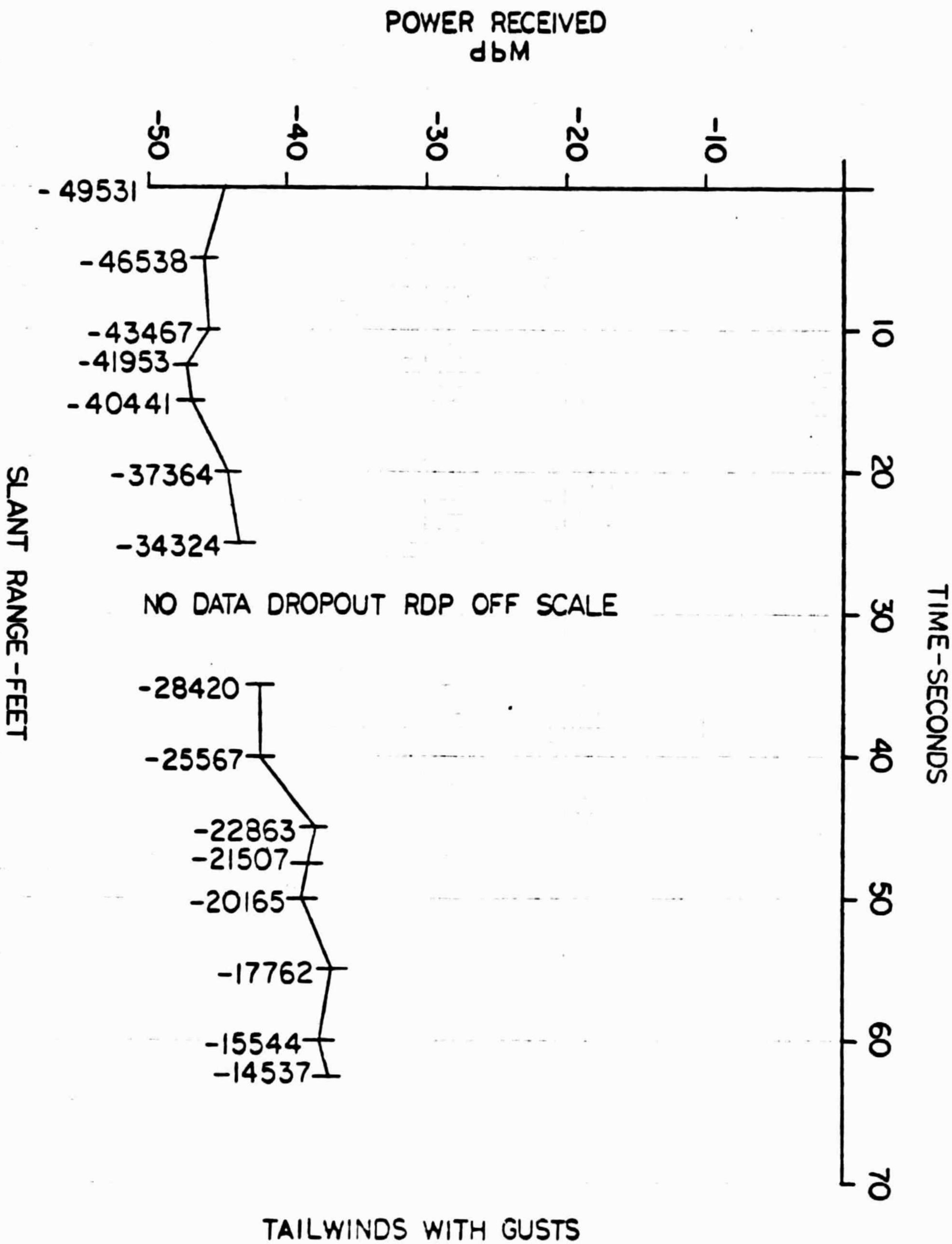
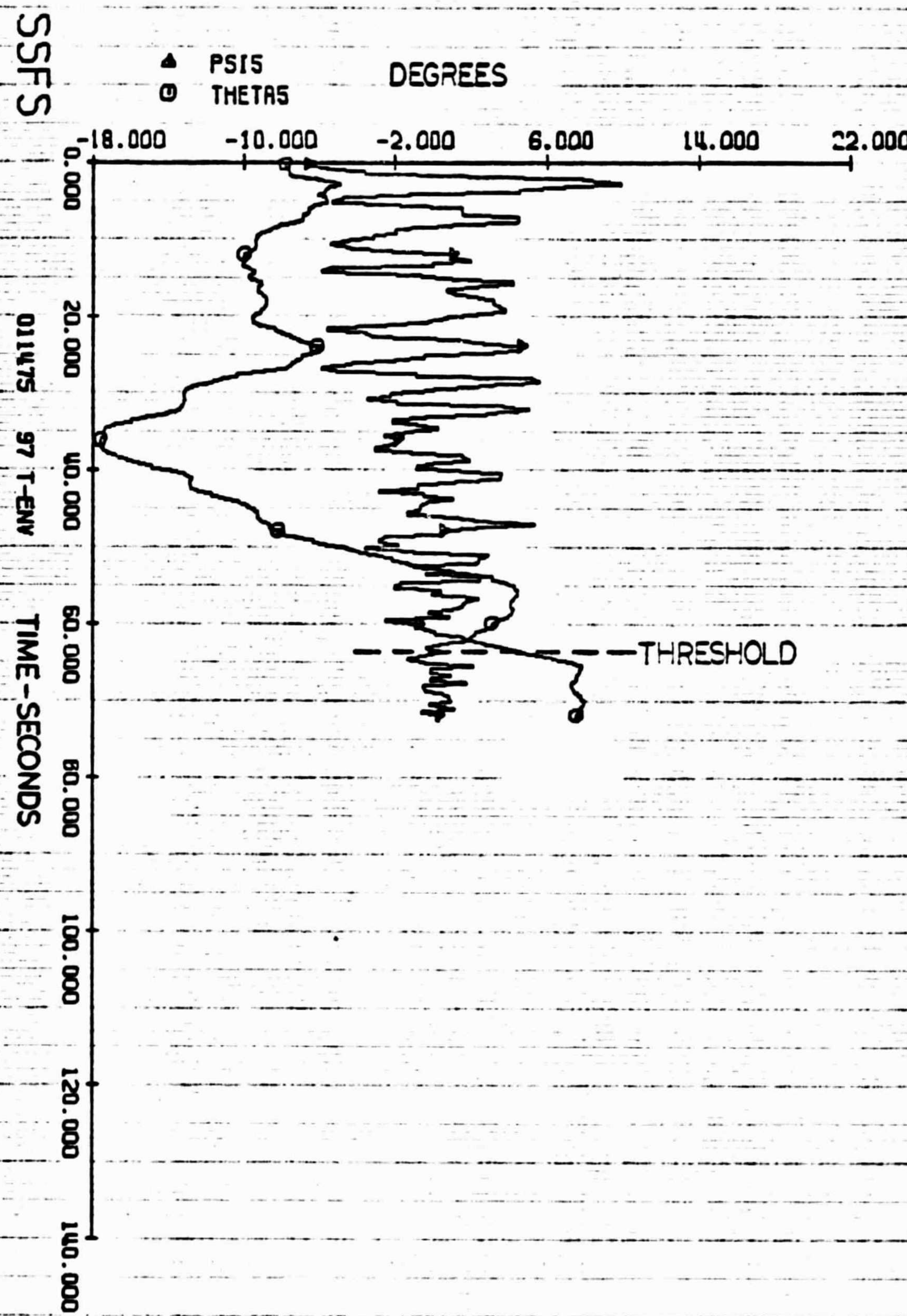


TAILWINDS WITH GUSTS
AZIMUTH STATION

FIGURE 17



TAILWINDS-LEFT TO RIGHT
AZIMUTH STATION

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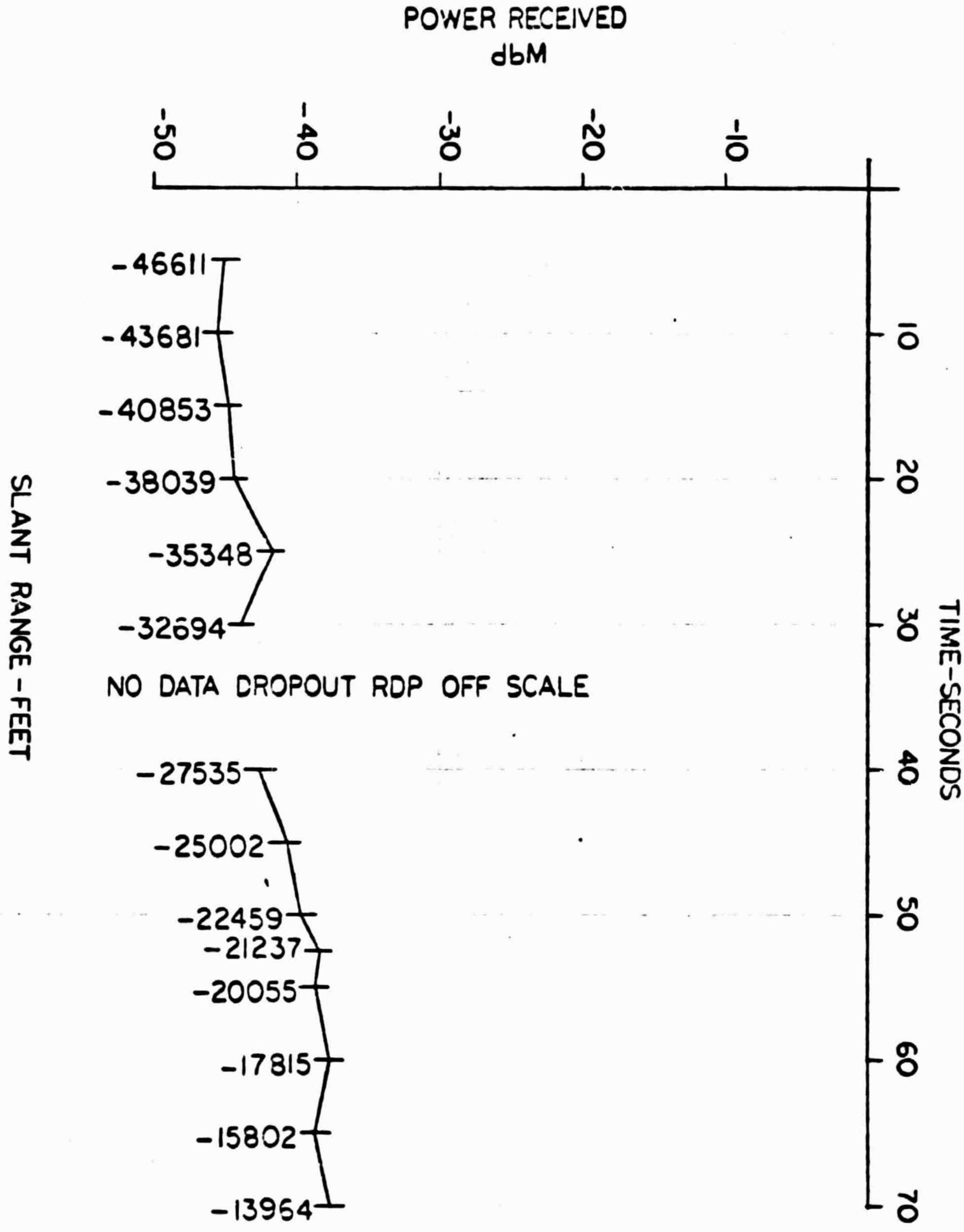

CROSSWINDS-LEFT TO RIGHT
AZIMUTH STATION

FIGURE 19

6.0 REFERENCES

1. Erwin, Harry O. Jr. and Johnson, Marvin L, "The Effect of MSBLS Antenna Pattern Nulls Caused By the Air-Data-Probe," JSC Internal Note 09424, 14 January 1975.